

# Analysis of Passive Vibration Measurement and Data Interrogation Issues in Health Monitoring of a HMMWV Using a Dynamic Simulation Model

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# Motivation

HMMWV comes in over a dozen variants:

- Some heavier than others;
- Variation in loading;
  - Durability of suspension,
  - Frame and cross members.
- A method is desirable through which passive vibration response is used to detect faults.



# Issues

Issues with using vibration for fault detection:

- Which frequency range?
- Sensors, how many and where to place?
- Damage variety (suspension, frame, etc.).
- Non-stationary excitation due to terrain:
  - L/R wheels in phase,
  - L/R wheels out of phase,
  - Must identify operating regime first.
- Variability from vehicle-to-vehicle.

# Approach

87 degree of freedom dynamic model:

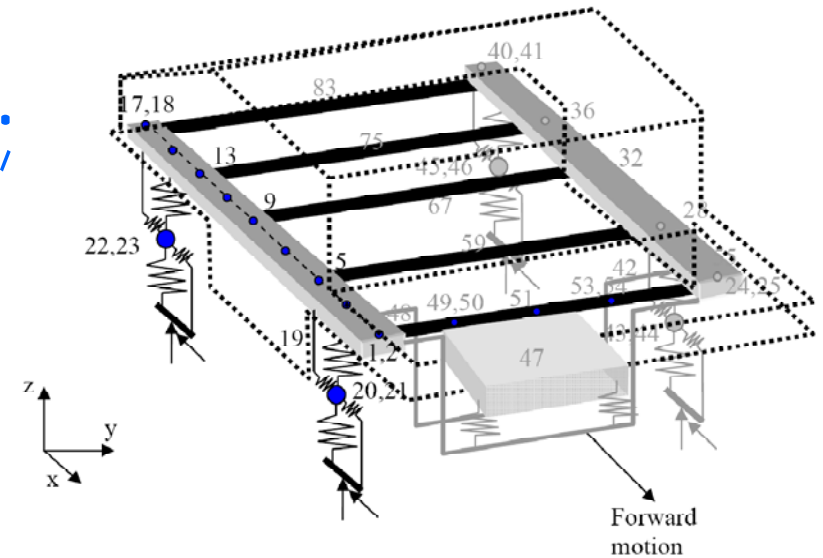
$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{f\}$$

- x and z forcing functions;
- Free response analysis;

$$[M]^{-1} [K]\{X\} = \lambda \{X\}$$

- Force response analysis;

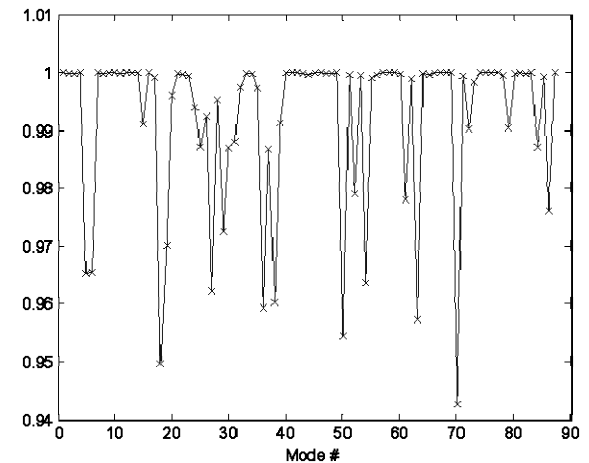
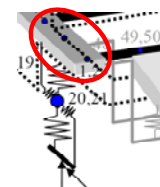
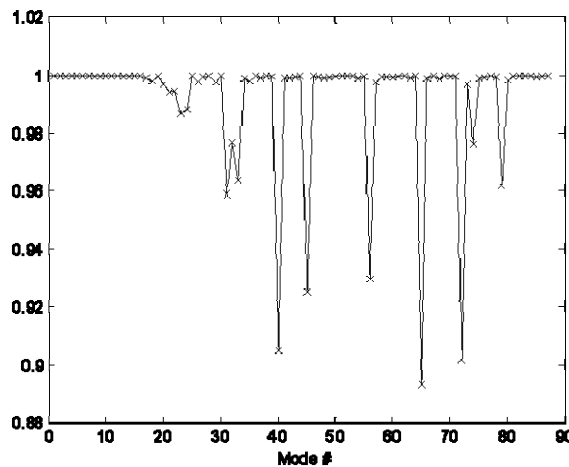
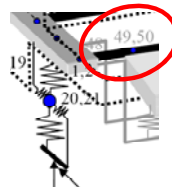
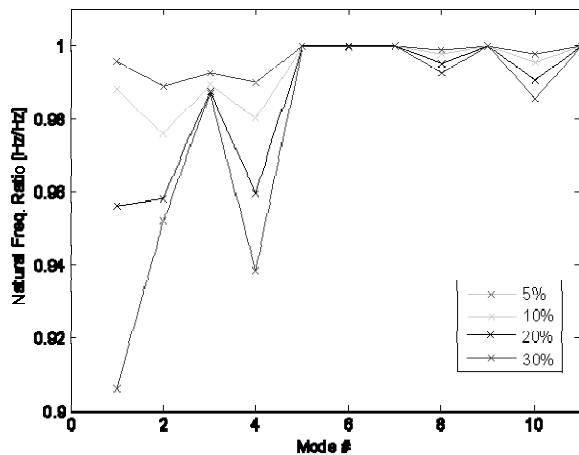
$$\begin{aligned} \frac{d}{dt} \begin{Bmatrix} \{x\} \\ \{\dot{x}\} \end{Bmatrix} &= \begin{bmatrix} [0] & [I] \\ -[M]^{-1}[K] & -[M]^{-1}[C] \end{bmatrix} \begin{Bmatrix} \{x\} \\ \{\dot{x}\} \end{Bmatrix} + \begin{bmatrix} [0] \\ [M]^{-1} \end{bmatrix} \{f\} \\ &= [A] \begin{Bmatrix} \{x\} \\ \{\dot{x}\} \end{Bmatrix} + [B]\{u\} \end{aligned}$$



# Results (Free Response)

Suspension, cross member, and frame damage:

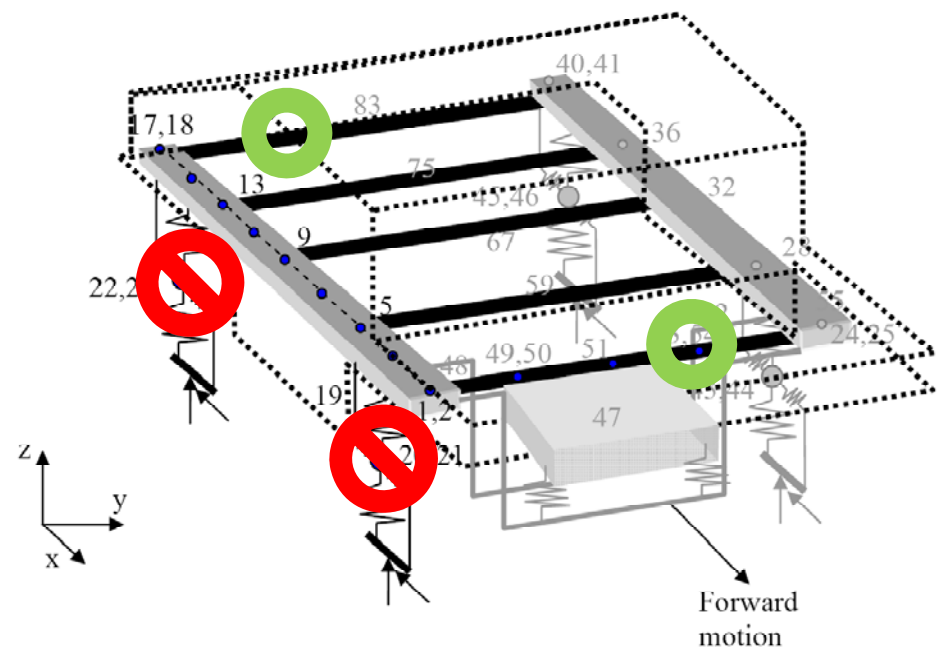
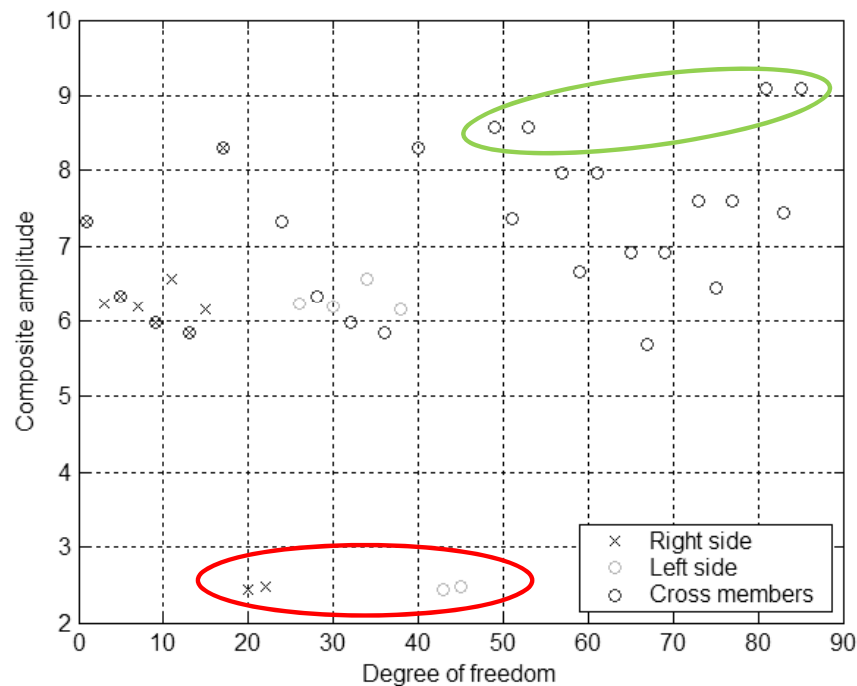
- Low, high, and broad frequency changes,
- 40-50% damage results in 10% variation.



# Results (Free Response)

Modal deflection shapes show that:

- Sensors on F/R cross members are optimal,
- Sensors on wheel are suboptimal (filtering).

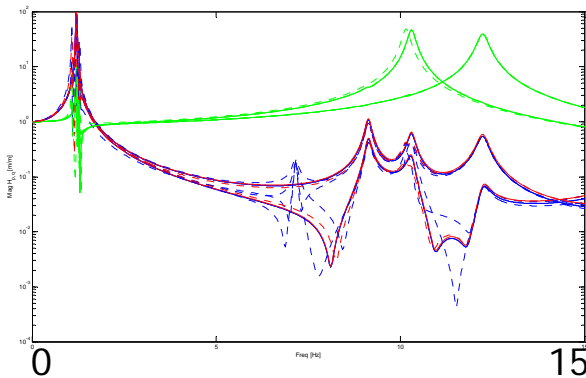


# Results (Force response)

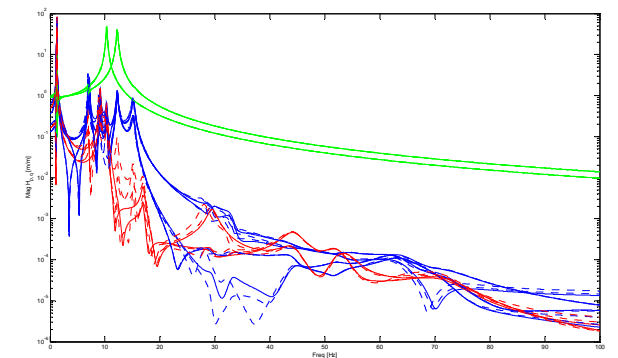
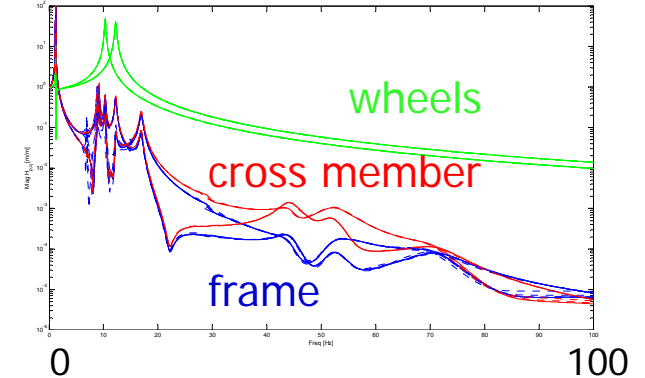
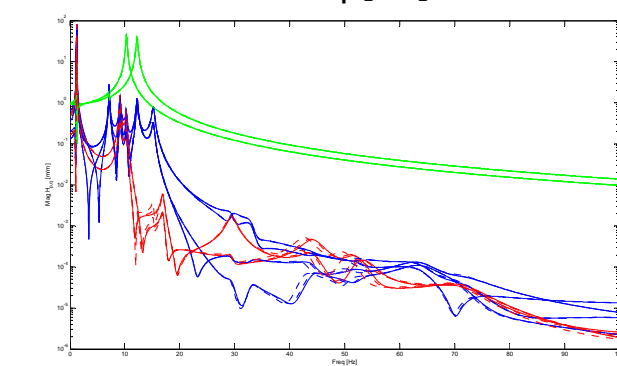
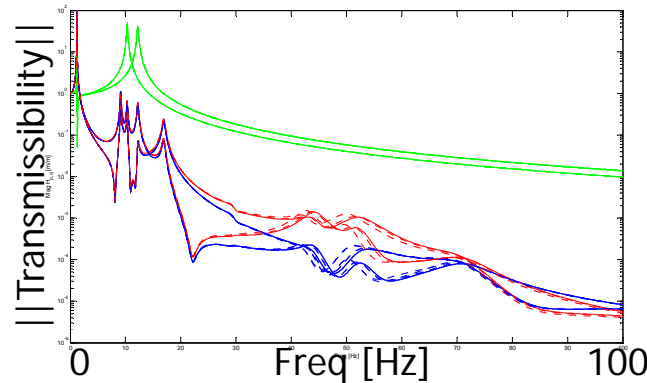
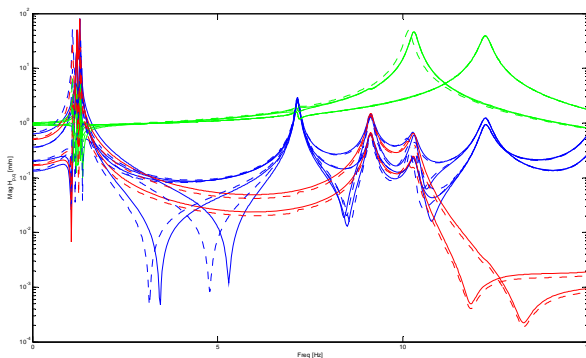
Faults in suspension, frame, cross members are:

- detected in different frequency ranges;
- best detected for certain terrains (modes).

L/R in phase



out of phase

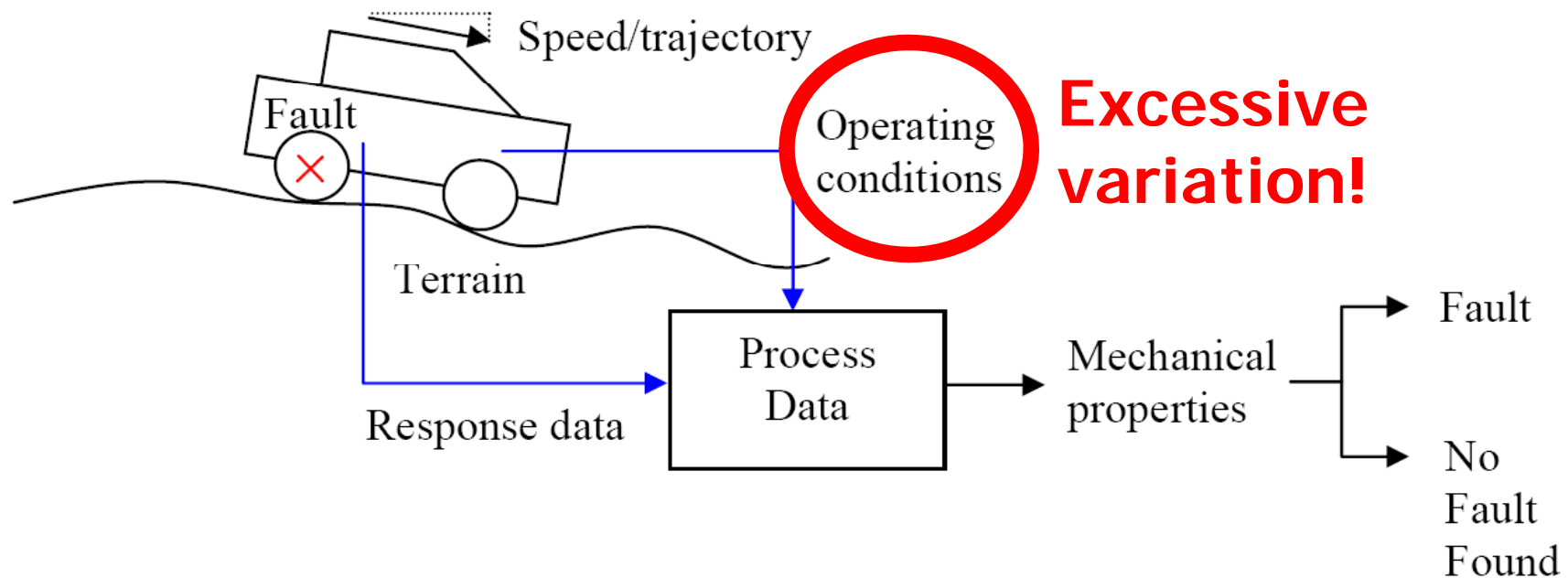




# Technical Barrier

HMMWV forced response varies significantly:

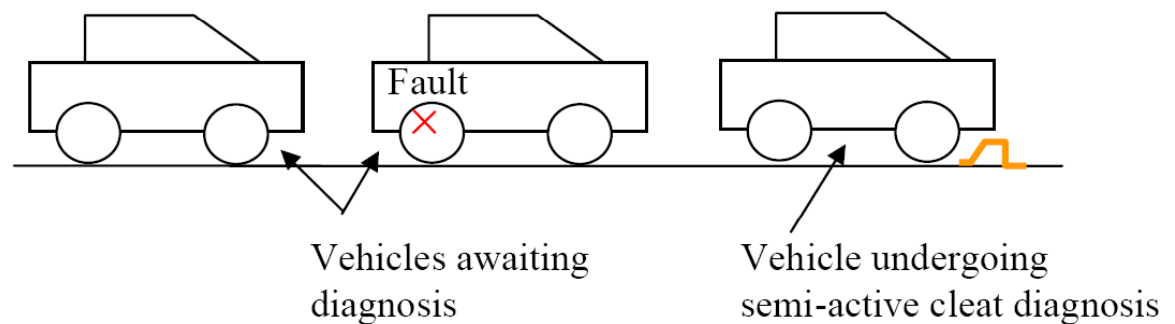
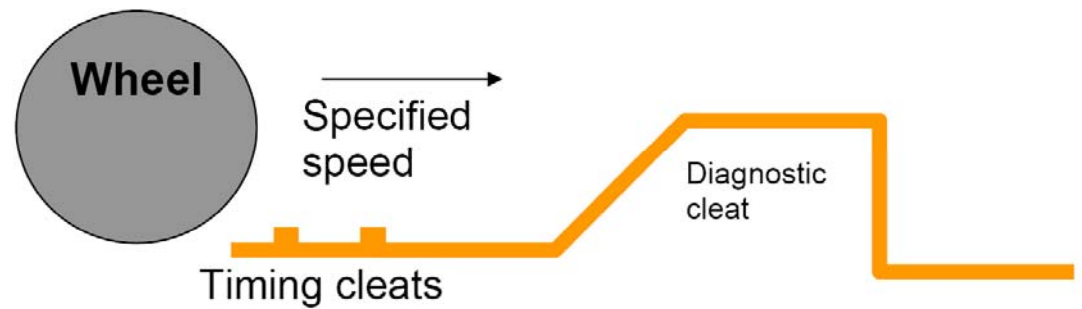
- Without regime recognition, fault detection is difficult using conventional methods.



# Proposed Approach

Method to control vibration input for diagnosis:

- Timing, and
- diagnostic cleats.
- “Weigh station” approach will target certain faults.



# Experimental Setup

Pickup truck with 2 vertical accelerometers:

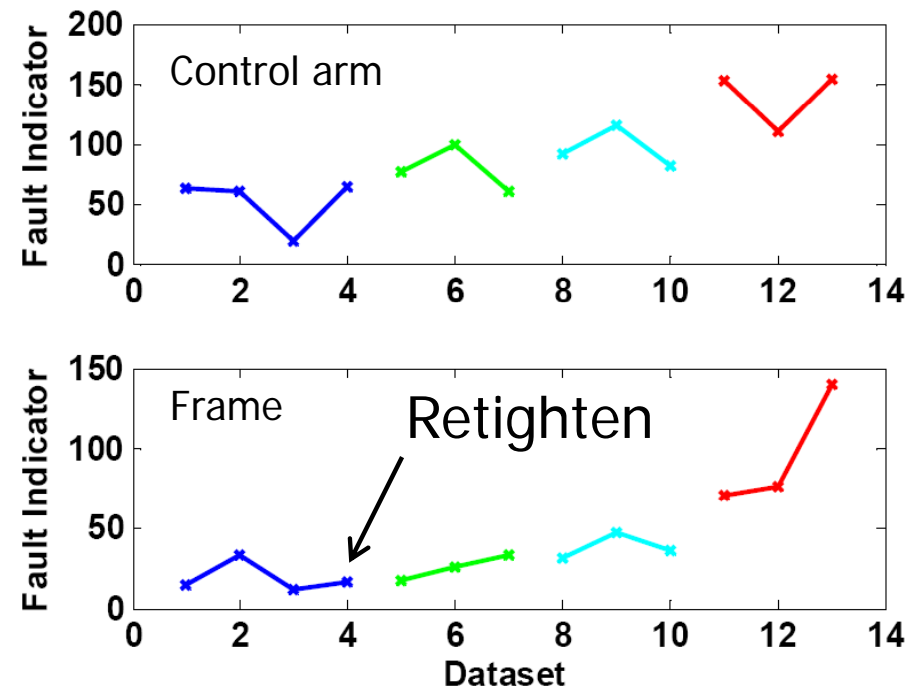
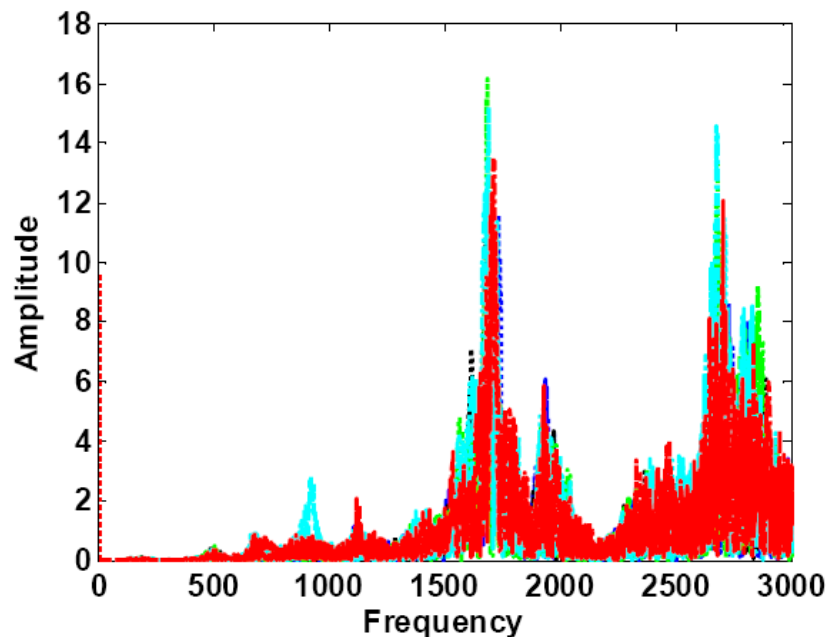
- F/R control arm and F/R frame.



# Experimental Results

Sway bar link loosened to 400, 200, 0 lb-in:

- Low freq insensitive to fault;
- Both sensors sensitive from 2.6-3.9 kHz.



# Conclusions

Fault detection using vibration data is feasible:

- Free response (modal) changes depend on frequency range;
- Forced response changes depend on regime;
- To control variability in fault indicators, diagnostic clear approach is proposed;
- Experiments indicate fault in stabilizer bar link can be detected amidst variability in data.